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PROSTHETIC REHABILITATION OF MISSING TEETH AND ORAL HEALTH IN THE ELDERLY

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ACADEMIC DISSERTATION

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1. LIST OF ORIGINAL PUBLICATIONS

The present thesis is based on the following original publications, which will be referred to in the text by their Roman numerals.

I Nevalainen MJ, Närhi TO, Siukosaari P, Schmidt-Kaunisaho K, Ainamo A. Prosthetic rehabilitation in the elderly inhabitants of Helsinki, Finland. J Oral Rehabil 1996 Nov;23(11):722-8.

II Nevalainen MJ, Rantanen T, Närhi TO, Ainamo A. Complete dentures in the prosthetic rehabilitation of elderly persons: five different criteria to evaluate the need for replacement. J Oral Rehabil 1997;24:251-8.

III Xie Q, Närhi TO, Nevalainen MJ, Wolf J, Ainamo A. Oral status and prosthetic factors related to residual ridge resorption in elderly subjects. Acta Odontol Scand. 1997; 55(5):306-13. *

IV Nevalainen MJ, Närhi TO, Ainamo A. Oral mucosal lesions and oral hygiene habits in the home-living elderly. J Oral Rehabil 1997;May;24(5):332-7.

V Nevalainen MJ, Närhi TO, Ainamo A. Five-year follow-up study on the prosthetic rehabilitation of the elderly in Helsinki, Finland. J Oral Rehabil: in press.

* This article has also been published in Qiufei Xie's dissertation in 1997.

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2. ABBREVIATIONS

ARPD = acrylic removable partial denture

CD = complete denture

FPD = fixed partial denture

HAS = Helsinki aging study

MRPD = removable partial denture with metallic framework

RPD = removable partial denture

RRR = residual ridge resorption

3. ABSTRACT

The number of elderly has almost quadrupled in 1950-1990. At the same time total loss of teeth, edentulousness, earlier prevalent among the elderly is declining. In Western societies, open teeth spaces on the visible anterior part of dental arch are considered to be unacceptable and socially degrading. Reduced dentition may also modify food intake leading to vitamin deficiency or even malnutrition. Different methods to rehabilitate the missing teeth have been developed since the ancient times, but their effect to the oral health of the aging patient is poorly documented. Hardly any scientific data exist on the status and quality of prosthetic rehabilitation in the elderly.

As a part of the population-based medical Helsinki Aging Study (HAS), the oral and dental status and oral hygiene habits of 364 old elderly, born in 1904, 1909 and 1914 and living in Helsinki, was examined in 1990 and 1991 (Oral-HAS). The main objective of this thesis was to document the current status and later possible changes in prosthetic rehabilitation, need for prosthetic treatment, residual ridge resorption (RRR) related to prosthetic factors, health of oral mucosa and denture hygiene habits. In the five-year follow-up, we also seeked to verify the validity of the largely presumed changes in the number of remaining teeth and the effect of prosthetic rehabilitation on the oral health.

Two subjects with full dentition of 32 teeth were found. A total of 54% of all studied subjects had 1 to 32 teeth remaining, 18% had 18-32 teeth, 16% had 9-17 and 20% had only 1-8 remaining natural teeth. When the third molars were excluded the mean number of teeth among these 196 subjects was 13.2. Fourteen per cent of the whole study group did not have any kind of dental prosthesis. Dentate subjects had slightly more than one third (37%) of their missing teeth replaced with removable or fixed prostheses (excluding third molars). However, further 5% of the missing teeth were judged by the examiner to need additional rehabilitation.

Forty-six per cent of the subjects were totally edentulous. Over the five-year follow-up, edentulousness increased only marginally: five subjects became edentulous. Complete denture (CD) in both jaws were worn by 94% of the edentulous, only maxillary CD was worn by 2% and 4% did not wear any denture at all. Only one subject had an implant-supported overdenture in the mandible. Seventy-four per cent of all the subjects had removable complete or partial dentures and 24% had fixed prosthesis. The mean number of artificial crowns was 1.8 and 0.2 for fixed partial dentures. The fixed prosthesis was more common in women than in men. The prevalence of artificial crowns was significantly higher in the younger age groups than among the oldest age groups.

A subgroup of 144 subjects wearing a full set of CDs was examined separately. The age, condition, and functional properties of the CDs were assessed. Twenty-five per cent of the CDs turned out to be more than twenty years old. Almost 90% of all CDs were sound. When the functional properties were compared with the age of the CDs, it was found out that all properties, except articulation, worsened with the increasing age of the dentures. Only 6% of the mandibular CDs had good retention compared to the 38% in the maxilla. Hence, unsatisfactory functional properties were the main indication for denture replacement needs. Based on clinical examination, 84% of the subjects needed new dentures, but only 10% of the subjects felt a subjective need for replacement.

In two fifth of the whole study group at least one oral mucosal lesion was detected. These lesions were most common among the edentulous CD-wearers: half of the edentulous subjects and one third of partly dentate RPD wearers had soft tissue changes. The total number of lesions per person correlated positively with the total number of subject's daily drug taking. The prevalence of lesions not related to the use of dentures was rather low, fewer than ten per cent in all cases. The denture related soft tissue changes were more common: inflammatory lesion under maxillary denture was the most frequent finding in 25% of the CD wearers.

Nearly all the subjects, 96% of the CD wearers and 98% of the partially dentate RPD wearers reported they clean their dentures at least once a day. No significant association was observed between the number of mucosal lesions and denture cleaning frequency. Negative correlation was found between the number oral mucosal lesions and the daily brushing of denture bearing soft tissues.

Forty-six per cent of the basic Oral-HAS group participated in the follow-up study after 5-years. From 1990 to 1996, half of these subjects had lost one or more natural teeth. In 44% of the whole 5-year follow-up group prosthetic rehabilitation had slight changes. Forty per cent of the subjects were totally edentulous. Five persons in this group were "new edentulous" CD users. Sixty per cent of the follow-up group was partly dentate. Statistical analysis revealed that loss of natural teeth was related to wearing of removable dentures and male gender at the baseline. The elderly with removable dentures had higher numbers of salivary microorganisms and higher root caries incidence than those with natural dentition.

A clear need for prosthetic treatment among the elderly was verified. This need for treatment was more often objective than subjective. The idea of rehabilitation of every missing tooth should be abandoned. In many cases the patient would benefit more from securing the function of the occlusion with strategically located fixed prosthesis.

4. INTRODUCTION

During the 20th century, the life expectancy in Finland has grown from 45 years to 75 years. Life-threatening infectious diseases have almost disappeared and many chronic diseases can be taken care by long time medications and surgery. At the same time, also oral health has slowly improved. At the end of 1950s, the population over seventy years of age was mainly edentulous (Kalijärvi, 1963), the mean number of teeth was estimated to be one. In the year 2000, the mean number of retained teeth had increased to be nine and can be expected to be 14 or more in 2010. This new group of partly dentate elderly with many slowly progressing diseases and multiple medications presents an entirely new group of patients in dentistry. There is hardly any information about the quality of prosthetic rehabilitation and its effect on oral health of the elderly.

Only few studies have been performed on prosthetic rehabilitation of the elderly in Finland. The Mini-Finland study performed in 1978-1980 (Vehkalahti *et al.*, 1991) included only some subjects over 70 years of age and it described mainly social, economic and logistic problems connected with complete dentures (Tuominen, 1985; Ranta, 1987). Most of the earlier studies have been cross-sectional in nature. Although some clinical studies regarding the dental health of the elderly have been conducted in Northern countries (Ainamo & Österberg 1992, Axell 1976; Axell & Öwall 1979), there have been no studies containing data on prosthetic rehabilitation and its effect on oral health among the very old population.

The age of complete dentures (CD) among the elderly has been reported to be high (Salonen, 1994; Peltola *et al.*, 1997). The longer the denture has been worn the fewer problems the patient experiences (Powter & Cleaton-Jones, 1980). However, the patients' subjective and dentists' objective opinions about the quality of prostheses are not always in agreement. Several different methods have been used to evaluate the condition of dentures and the need for prosthetic treatment, but no comparisons between the evaluation methods have been made.

The oral mucosa becomes thinner and more vulnerable to external injuries with the advancing age. Numerous medications lead to hyposalivation (Närhi *et al.*, 1992), which further compromises the health of the fragile oral mucosa. Loss of saliva increases the number of oral bacteria and their metabolic products in the mouth. The deteriorating motoric skills tend to weaken oral hygiene efforts, which further contributes to increased growth of many microorganisms. Thus the prevalence of mucosal changes has been reported to be high among the elderly (Tervonen, 1988; Vehkalahti *et al.*, 1991). Ill-fitting dentures are known to increase the risk of oral mucosal changes. Data about the associations between prosthetic factors, denture hygiene and presence of oral mucosal lesions in the elderly is very limited.

Poor retention of complete denture is one of the main oral problems in the edentulous persons. Poor retention is often related with loss of CDs' bone support. Reasons for residual ridge resorption (RRR) are multiple and may vary among individuals (Atwood, 1962 and 1971; Devlin & Ferguson, 1991; Nishimura *et al.*, 1992; Nishimura & Atwood, 1994). It begins after extraction of teeth and progresses at varying speed for the rest of the life (Tallgren, 1972). Both local and systemic factors may affect the rate of RRR. The role of local prosthetic factors in the RRR is poorly understood (Carlsson &Persson, 1967).

The aim of this doctoral thesis was to describe the present prosthetic rehabilitation, the adequacy of received prosthetic treatment and subjective and objective needs for the prosthetic treatment among home dwelling elderly in Helsinki, Finland. A further aim was to evaluate, after a five-year follow-up period, changes in the prosthetic status and the effect on prosthetic treatment on the oral health. This thesis is based on five articles describing prosthetic rehabilitation and oral health among a representative sample of 75-, 80- and 85-year old Helsinki residents.

5. REVIEW OF THE LITERATURE

5.1. Population studies

Rapid demographic changes in the Western countries have lead to fast increase of population over the age of 65. This has turned dental health providers' interest towards the elderly and some population based studies on oral health have been completed that also include elderly persons (Table 1).

Table 1. Population based studies in the elderly

Author	Period of study	Age	% edentulous	Area	Remarks
Kalijärvi, 1963	1959	70+	men 70%, women 100%	Finland	National, rural
Todd &Walker, 1980	1968	Adults	37%	UK	National
Todd&Walker, 1980	1968	75+	88%	UK	National
Ainamo, 1983	1970	65+	54%	Finland	National
Mini-Finland, 1991	1977	65+	men 51%, women 65%	Finland	National
Todd *et al*., 1982	1978	Adults	29%	UK	National
Todd *et al.*, 1980	1978	75+	87%	UK	National
Ainamo, 1983	1980	65+	67%	Finland	National
Österberg *et al.*, 1984		70	men 46%, women 55%	Sweden	Göteborg
Tervonen *et al.*, 1985	1982	65	61%	North Finland	North Finland
Kirkegaard, 1986	1981-2	65-81	59%	Denmark	National
Miller *et al.*, 1987	1985	65+	41%	USA	National, working adults
Kalsbeek *et al.*, 1991	1986	65-74	65%	Netherlands	National
Todd&Lader, 1991	1988	Adults	20%	UK	National
Todd&Lader ,1991	1988	75+	80%	UK	National
Ainamo *et al.*, 1991	1990	65+	46%	Finland	National
Sakki *et al*., 1994	1990	55	39%	Finland, Oulu	City of Oulu
Hartikainen, 1994	1994	65	61%	Finland, Oulu	City of Oulu
Henriksen *et al*., 2003	1996-7	85.1(mean)	59%	Norway	National
Kelly *et al.*, 2000	1998	All adults	12%	UK	National
Kelly *et al.*, 2000	1999	75+	58%	UK	National
Aromaa&Koskinen, 2002	2000	65+	men 37%, women 44%	Finland	National
Aromaa&Koskinen, 2002	2000	85+	men 51%, women 60%	Finland	National

In Finland, clinical dental studies of the elderly have been scarce. Some attempts to describe the prevalence of edentulousness, number of missing teeth and factors influencing the use and accessibility of dental services have been carried out by the means of

questionnaire studies (Markkula *et al.*, 1973; Rantanen, 1976; Murtomaa, 1977; Ainamo, 1983; Nyman, 1983 & 1990), or with special groups like institutionalised elderly (Mäkilä, 1976, 1977abc; Ekelund, 1983). These studies have mainly involved rural inhabitants (Tervonen, 1988). Only the nation wide Mini-Finland Health Study carried out in 1978-1980 (Vehkalahti *et al.*, 1991) and Health 2000 Study (Aromaa & Koskinen, 2002) have covered the dental health of independent elderly population in Finland.

5.2. Number of retained teeth in the elderly

In most cases, the process of loosing teeth is a slowly progressing life-long process leading eventually to edentulism. Today, natural teeth are retained longer than before shifting the age of total loss of teeth towards older age groups. In 2000, the total loss of teeth among Finns in general was only half of that reported in 1980, and the dentate formed the majority in almost all age groups (Aromaa & Koskinen, 2002). From 1980 to 2000, the number of dentate Finnish women has increased 20% and the corresponding number for men is 10% (Vehkalahti *et al.*, 1991; Aromaa & Koskinen, 2002).
Since this positive development in dental health started in 1980's, the overall increase in the number of partly dentate citizens has been astonishingly rapid. Even among the retired citizens, aged 65 years and over, this increase was 35% (Ainamo & Murtomaa, 1991). Several factors have been mentioned to explain this change. First of all, The Primary Health Care Act (66/1972) that became valid in April 1972 was designed to provide the population with general health education and prevention of diseases. It turned to be successful in the dental domain and managed to combine improved oral hygiene habits and healthier life style behaviour with generally better living conditions and financial situation at that time. Increased use of fluoridated toothpaste since its introduction in Finland in 1962 has obviously played an important role in this development (Ainamo & Murtomaa, 1991). Higher educational level in general might have contributed to the positive development as well (Vehkalahti *et al.*, 1991; Aromaa & Koskinen, 2002).
Clear socio-economic and regional differences in oral health among the Finnish elderly still exist. Retired people in the Northern Finland have lost all their teeth twice as often as their fellow citizens in the South (Aromaa & Koskinen, 2002). This large difference is somewhat surprising considering the fact that the Finnish government first started to carry out the Primary Health Care Act in the Northern and Eastern Finland, and in many cases the whole rural community was entitled to communal dental care. However, not only the geographical place of living, but also the type of residence seems to be important. Home dwelling independent elderly have often a better oral health and more retained teeth than the frail, dependent or institutionalised elderly (Chrigström *et al.*, 1970; Leake & Martinello, 1972; Marken & Hedergård, 1970; Österberg *et al.*, 1984, 1998; Floystrand *et al.*, 1982).

5.3. Causes for the loss of teeth

During and after the World War II, many necessities of life were rationed in Finland. Sucrose was released from rationing in 1954, leading to a radical increase in sugar consumption. This may have been the most fundamental etiological factor for the dramatic increase in caries among the Finnish children in the beginning of the 1950's (Rytömaa *et al.*, 1980). Not surprisingly, increase in the early-age-caries incidence lead to the situation where caries became the main reason for extractions among the whole Finnish population (Ainamo *et al.*, 1984). On the other hand, the view that periodontitis rather than caries was

the leading cause of tooth loss among adults remained a general conception in dentistry. Many published articles support this perception (Burt *et al.,* 1985; Homan *et al.,* 1988).
In the early 80s, caries incidence was high among young and old adults, and teeth were more often removed because of severe dental decay rather than periodontal disease (Ainamo *et al.,* 1984). This seems to be in accordance with other Scandinavian studies. In Sweden, 43% of the 75-79-year old and 33% of the 80-84-year old persons living in Stockholm had caries (Marken & Hedegård, 1970). A recent Swedish study found that the major reason for tooth extraction among the elderly was dental caries (60% of the cases) and only half as many teeth were extracted because of periodontal disease (Fure, 2003). Studies conducted in other European countries document parallel figures (MacEntee & Scully, 1988; Bouma *et al.,* 1987). In addition to caries and periodontal disease, non-disease factors such as general attitudes and behaviour, characteristics of the health care system, and dental attendance patterns may play a role in the aetiology of edentulousness (Bouma *et al.,* 1987). Tuominen and co-workers (1983) concluded that scarcity of dental services is usually the factor that prevents people from preserving their natural dentition.
Loosing teeth is a complex, multi-factorial process and a low number of remaining natural teeth does not necessarily demonstrate negative attitudes and neglected dental health *per se*. However, it might be an indication of frequent dental emergency visits at earlier times, when extractions were the main treatment procedure (Floystrand *et al.,* 1982).

5.4. Edentulousness

In 1970, twenty-three per cent of the adult Finns, aged 15 years and more, were totally edentulous (Markkula *et al.,* 1973). Ten years later the proportion of edentulous people at the population level was unchanged, but the number of totally toothless individuals in the age group of 64-year old and older was still growing (Ainamo, 1983). This increase of edentulousness among the older age group has been explained to be a consequence of a rapidly improving availability of dental care, increase in number of extractions as a consequence of this, decreased tolerance of physical imperfection, and increased vanity in social communication habits in general. However, clear improvement has taken place in this domain since then. Not surprisingly, this reduction in the edentulousness, from 22 % in 1980 to 11 % in 1990, has been fastest in Southern Finland. This improvement, two per cent per year, has taken place mostly among the middle-aged people (Tuutti *et al.,* 1986; Aromaa & Koskinen, 2002). Since the Mini Finland Study twenty years ago, the number of totally edentulous individuals in the whole Finnish population has half-folded (Markkula *et al.,* 1973; Ainamo & Murtomaa, 1991; Aromaa & Koskinen, 2002). Today, absence of teeth is rare among the 30-44 -year old citizens. Unfortunately it is still common in older age groups and more frequent among over 54-year old women than men of the same age (Aromaa & Koskinen, 2002).

Historically, edentulousness has been less common in densely populated wealthy areas in the South and South-West-Finland than elsewhere in the country (Vehkalahti *et al.,* 1991). Several studies in Finland and abroad have confirmed the influence of the living environment on the prevalence of edentulism (Markkula *et al.,* 1973; Nordenram & Böhlin, 1981; Kalimo *et al.,* 1989; Luan *et al.,* 1989; Aromaa & Koskinen, 2002). Since 1970's, this socio-economic and geographic imbalance has slightly faded in Finland. However, still today, the number of toothless retirees is two times higher in the Northern part of the country than in the South Coast (Ainamo, 1983; Ainamo & Murtomaa, 1991; Aromaa & Koskinen, 2002). Similar development has clearly taken place in other industrialized

countries (Axell & Öwall, 1979; Beal & Dowell, 1977; Lemasney & Murphy, 1984; Roder, 1975; Miller *et al.*, 1987; Todd & Lader 1991, Kelly *et al.*, 2000).

5.5. Need for prosthetic treatment

Loss of some or all of the natural teeth may be experienced either as a restricted local body injury or a socially limiting condition. Even though the dental condition and looks affect the judgement of facial attractiveness in mature age groups of 65 to 75-year olds (York & Holtzman, 1999), the need to replace missing teeth has reported to be relatively low (Tervonen, 1988). Generally, subjective need for dental treatment among edentulous Finns (26%), is only half of that among the 30-65-year old citizens (53%) (Aromaa & Koskinen, 2002).

Regarding dentate subjects, it seems that in a reduced natural dentition, as long as the person has more than three to four functional units left and the aesthetic and functional requirements have been fulfilled, there is little or no social and functional need to replace missing teeth (Käyser, 1981; Käyser *et al.*, 1987; Leake *et al.*, 1994). Thus, a shortened dental arch (SDA) *per se* does not necessarily trigger any subjective need for prosthetic treatment (Käyser *et al.*, 1987, Meeuwissen *et al.*, 1995). SDA may even provide such durable occlusal stability that free-end RPD cannot automatically be considered to be an improvement (Witter *et al.*, 1994). Furthermore, free end RPD in the lower jaw did not prevent TMD, and did not improve oral function in terms of oral comfort. Even a total loss of teeth and the duration of edentulousness or the number of set of CDs has no correlation to TMD (Raustia *et al.*, 1997).

Over-treatment of shortened dental arches with removable dentures may in some cases cause caries and periodontitis for the remaining dentition thus worsening oral health (Budtz-Jörgensen & Isidor 1990, Steele *et al.*, 1997). One must also keep in mind that RPD-patients need regular surveillance through a recall system (Vermeulen *et al.*, 1996). This is not an easy task when treating older age groups, bearing in mind that they are the part of population that uses least the dental services (Aromaa & Koskinen, 2002).

All partly or totally edentulous denture wearers are not satisfied with their oral condition. Ten per cent experiences continuous problems with their denture (Laine, 1982). Existing RPD can even be less satisfying than no denture at all. However, in a case where RPD adds more occlusal units to the dentition, patient's satisfaction seems to increase (Van Waas *et al.*, 1994). Indeed, a high correlation has been reported between satisfaction with dentures and subjective opinion about the chewing ability (Langer *et al.*, 1961). Decreased psychomotor(ic?) skills and high age when obtaining the first CDs may be one reason why the elderly may have difficulties in using removable dentures (Laine, 1982; Käyser & Witter, 1985). In most cases, dissatisfaction is related with the problems wearing a mandibular CD (Langer *et al.*, 1961), the main problem being poor retention during speaking and eating (Mäkilä, 1974; Lappalainen *et al.*, 1985).

Today, the constantly increasing number of elderly with natural teeth require new treatment strategies (Berkey, 1988). The Dentist's and patient's sometimes conflicting opinions regarding the treatment needed may sometimes complicate treatment planning (Stark & Holste, 1990). In most cases, patients are seeking for good aesthetics and comfort, whereas dentist may address more the importance of function (Käyser *et al.*, 1987). As already discussed, the minimum number of teeth needed to satisfy functional and social demands

varies individually. This depends on multiple local and systemic factors, such as periodontal condition of the remaining teeth, occlusal activity and a person's adaptive capacity and age (Kalk *et al.*, 1993). Thus, the greatest challenge for the clinician is to choose between either treating the patient with the risk of producing iatrogenic disease, or not treating the patient with the risk of more damage occurring to the masticatory system (Budtz-Jorgensen, 1996).

5.6. Rehabilitation with removable prosthesis

On a population level, total or partial loss of natural teeth *per se* does not necessarily mean that the missing teeth have to be replaced with dental prostheses. For example, in the oldest Finnish age groups where the number of missing teeth is highest (Vehkalahti *et al.*, 1991; Aromaa & Koskinen, 2002), the elderly often find reduced dentitions socially and functionally satisfactory without having a subjective need for dental treatment (Grabowski & Bertram, 1975; Rantanen, 1976; Mäkilä, 1979, Meeuwissen *et al.*, 1995). The dentist's objective needs for rehabilitation alone are not enough to justify treatment (Käyser *et al.*, 1987).

There are no generally accepted criteria for replacing missing teeth although every dentist would probably replace a missing upper incisor. The replacement of posterior teeth that does not directly improve the function of dentition, has been considered to be less important (Leake *et al.*, 1994) than prosthetic treatment in the anterior and premolar region (Käyser & Witter, 1985; Käyser, 1990). Some dentists have adopted a view that four occlusal units in shortened dental arches would be enough to maintain the healthy natural function of the dentition (Käyser, 1981).

As a consequence of differing clinical approaches and the dentists' and patients' individual psychological profiles, the number of removable prostheses is smaller than one may have expected. During the 1970's, about 40% of the Finns wore some kind of removable prostheses (Ainamo, 1983). By the late 1980's, the figure was decreased to 33% (Kalimo *et al.*, 1989). The frequency of partial dentures has been reported to vary between 3% and 15 % depending on the age group (Tervonen *et al.*, 1985; Hartikainen, 1994; Sakki, 1994). Similar percentages have been published in other countries (Björn & Öwall, 1979; Ettinger *et al.*, 1984).

The majority of Finnish studies have described the oral conditions of people living in rural areas (Alvesalo & Ainamo, 1968 a,b; Rantanen, 1976). For example, Tervonen and co-workers (1985) described the prevalence of removable dentures in the Western agricultural area of Finland being 6%, 38%, 68% and 80% among the 25, 35, 50, and 65-year old Finns, respectively. CD in both jaws was the most common type of rehabilitation in the age groups of 35 years and over and more common among women than men. Only a small number of studies have been conducted among those living in the cities (Markkula *et al.*, 1973; Ranta *et al.*, 1985). Unfortunately, in these studies the number of elderly inhabitants has been rather small, and therefore practically no data exists on prosthetic rehabilitation of home dwelling elderly. There is a handful of rather old studies of this type, but most of them are focused on special population groups (Laine & Murtomaa, 1985; Lappalainen *et al.*, 1985).

A set of CDs has been the most common form of prosthetic rehabilitation in Finland (Vehkalahti *et al.*, 1991; Aromaa & Koskinen, 2002). This is typical not only for Finland,

but applies to the whole 65-year-old and older Scandinavian population (Grabowski & Bertram, 1975; Rise & Helöe, 1978; Ekelund, 1983; Vehkalahti *et al.,* 1991). Inadequate rehabilitation has been common and totally untreated edentulousness has been surprisingly frequent (Ainamo, 1983; Ranta *et al.,* 1985; Laine & Murtomaa, 1985). Old age, long distance to the nearest dentist and low annual income have been related to the inadequate prosthetic treatment of edentulous persons (Mäkilä, 1974; Tuominen *et al.,* 1985). On the other hand, higher than secondary school education and short distance to the nearest dental surgery have been associated with good compliance of CD treatment (Ranta and Paunio, 1986; Aromaa & Koskinen, 2002). The highest proportion of edentulous persons treated with CDs has been found in the densely populated Southern Finland with no differences between the genders (Ranta *et al.,* 1985).

5.7. Rehabilitation with fixed prosthesis

Until now the number of fixed prosthesis has been rather low among Finns. Previously, this type of prosthetic treatment has not been able to reach the same coverage in popularity like in Sweden (Palmquist, 1986) where The National Insurance System has supported dental treatments since 1974. Few adult groups, for example Finnish war veterans, have been supported only since 1994. The fact that already more than thirty years ago as many as 30% of the 60- to 84-year-old elderly residents of the City of Stockholm had fixed partial dentures (Marken & Hedegård, 1970) demonstrates how fundamentally privileged and advanced the Swedish social system was at that time. Similar figures have been documented in Norway (Hansen & Johansen, 1976). However, in today's Finland, the improved number of retained teeth has finally increased the need of crowns and bridges, especially among the older age groups (Ranta *et al.,* 1987; Tervonen, 1988; Hartikainen, 1994).

The geographical place of residence not only influences the number of retained teeth, but also affects the prevalence of prosthetic rehabilitation with fixed prosthesis. Better dental health, higher numbers of natural teeth and rehabilitation with fixed prosthesis have all been found to be concentrated in the urban population in the Southern part of Finland (Markkula *et al.,* 1973; Kalimo *et al.,* 1989; Vehkalahti *et al.,* 1991; Aromaa & Koskinen, 2002). However, the same trend can clearly be seen elsewhere too: in the Northern part of the country the prevalence of treatments with fixed partial dentures in the age group of over 65-year-olds has documented to be 16 times higher today than in mid 90s (Näpänkangas *et al.,* 2001). It seems that in the future the need for conventional fixed partial denture rehabilitation will be highest among the citizen groups over 50-year of age (Näpänkangas *et al.,* 2001).

5.8 Residual ridge resorption (RRR)

Most of localised or general RRR takes place within one year after the loss of natural tooth or teeth (Carlsson & Persson, 1967). Resorption process is fastest during the first two to four months after the extractions and slows down gradually over time. However, some activity can be detected even after 25 years of constant denture wearing (Tallgren, 1972).

The speed and direction of alveolar bone loss is not similar in maxilla and mandible (Bergman & Carlsson, 1985; Salonen, 1994). Faster and more dramatic changes takes place in the mandible (de Baat *et al.,* 1993). In maxilla the changes occur evenly around the dental arch, but more on buccal and labial side than on the palatal side. In mandible resorption proceeds more in labio-lingual and vertical directions. Unlike in maxilla, the

speed of bone loss in mandible is different in different parts of the jaw: distal parts of the residual ridge disappear faster than the anterior parts.

Multiple factors can affect RRR. Age and gender differences are well documented: there is a clear correlation between mandibular RRR and female gender (Nishimura *et al.,* 1992). Systemic factors like osteoporosis, diseases related to thyroid function, medication, general lifestyle and local oral and prosthetic factors might all influence RRR (Kalk & de Baat, 1989; Kribbs, 1990; Krall & Dawson-Hughes., 1991; Xie *et al.,* 1997). Due to resorption the mental foramen and alveolar nerve can finally relocate on the crest of the alveolar bone. As a result of this, denture's functional properties can seriously deteriorate and wearing a mandibular denture can be a very painful experience.

Functional stability, a combination of stability and retention of the denture, is strongly affected by the degree of RRR and condition of the denture, especially in the lower jaw (Salonen, 1994). As a consequence of RRR, location of mandibular related muscle attachments are situated closer to the crest of mandibular bone. In combination with age related muscle atrophy and dry mouth, this may lead to a situation where denture wearing experience, especially of older dentures, is very unsatisfying and frustrating. Quite often renewal of the denture can provide the patient with a better fitting denture thereby improving personal satisfaction (Peltola *et al.,* 1997). However, mandibular over-denture supported by osteointegrated implants, seems to enhance the whole masticatory function more significantly by increasing biting force and improving the biting and chewing function (Haraldson *et al.,* 1988; Geertman *et al.,* 1999; Fontijn-Tekamp *et al.,* 2000).

Today, implant treatments are well-documented procedures to replace missing teeth or to provide retention for complete dentures. An early issued implant can even slow down the inevitable RRR. From the medical point of view there is limited contraindication for the use of osseointegrated implants (Oikarinen *et al.,* 1995), but the implant treatments are still too expensive for the majority of elderly. Despite the good treatment results the interest in this type of treatment among edentulous patient has remained low especially in countries where implant treatments are not reimbursed by the health care system (Palmquist *et al.,* 1991; Salonen, 1994).

All in all, loosing all natural teeth and having them replaced with CDs is a two edged sword: although a set of CDs is an adequate treatment of edentulousness, wearing of CDs may speed up the RRR and cause functional problems later on (Nishimura *et al.,* 1992).

5.9. Oral mucosal lesions and denture hygiene

Numerous mucosal lesions such as denture stomatitis, angular cheilitis, flabby ridge, irritation hyperplasia, traumatic ulcers and even cancer have been connected with the use of removable dentures (Budtz-Jörgensen, 1981). Up to seventy-six per cent of all oral mucosal lesions have reported to be inflammatory or reactive in nature (Silverglade & Stablein, 1988). In some biopsy studies, 15-25% of biopsies were diagnosed to be tumours, of which up to 3% were life-endangering (Weir *et al.,* 1987; Bhaskar, 1968). Some 25 years ago the percentual proportion of benign tumours or tumour-like lesions among the Finnish institutionalised elderly was 8 % (Mäkilä, 1977d). Generally, it seems that in the old age groups the prevalence of pre-malignant and malignant tumours is more than ten times higher than in younger age groups (Könönen *et al.,* 1987).

The prevalence of oral mucosal lesions varies between 52-59% depending on whether the subjects have lived independently or in an institution (Mikkonen *et al.,* 1984; MacEntee & Scully 1988; Jorge *et al.,* 1991; Espinoza *et al.,* 2003). It has been assumed that the oral health of the independently living elderly would be better than the oral health of the elderly living in the institutions. Vigild (1987) showed that approximately half of the institutionalised subjects had one or more pathological lesions in the oral mucosa. Surprisingly, some studies have reported totally opposite results suggesting that the prevalence of oral mucosal lesions is highest among the elderly living independently and lowest among those living in long-stay hospitals (Hoad-Reddick, 1989).

Candida albicans is the most common microorganism related to denture wearing (Kotilainen, 1972; Ritchie & Fletcher, 1973). Parallel findings from different studies show that almost three quarters of the older patients with denture stomatitis have *Candida albicans* in their palatal smear (Richie, 1973; Bastiaan, 1976). Budtz-Jörgensen and co-workers have published similar findings (1983). Several studies have been conducted to explore this relationship between yeasts and denture-induced stomatitis (Budtz-Jörgensen & Bertram, 1970; Bergman *et al.,* 1971; Budtz -Jörgensen, 1974, 1978; Budtz –Jörgensen *et al.,* 1975; Bastiaan, 1976; Sakki *et al.,* 1997).

Close correlation between the use of dentures at night and smoking has also reported (Barbeau *et al.,* 2003). The influence of patient's age, denture hygiene, use of drugs and denture wearing habits has been discussed in many papers (Salonen, 1994; Sakki *et al.,* 1997; Peltola *et al.,* 1997).

Also a low salivary flow rate may predispose the oral mucosa to the pathological changes because of its association with the presence of yeasts inside the mouth cavity (Sakki *et al.,* 1997). Number of several oral microorganisms has also been shown to be higher in denture wearers and in the elderly suffering from hyposalivation (Närhi *et al.,* 1993, 1994). Against this background the role of plaque removal cannot be stressed enough. Older people seem to be generally well informed of the importance of good oral and dental hygiene and their effect on oral health, but less aware of the poor results of their well-meaning cleaning of activities (Murtomaa & Meurman, 1992; Nevalainen *et al.,* 1997). Most older citizens brush their denture under running water at least once a day, but with the age related reduced manual dexterity the outcome is hardly ever good. It is obvious that written and verbal information alone is not enough to establish positive oral hygiene behaviour and results (Rantanen *et al.,* 1980). Indeed, repetitive cleaning demonstrations and motivation sessions may be the only way to attain longer lasting changes (Rise & Helöe, 1978; Ambjörnsen 1986).

Trauma induced by ill-fitting dentures has been supposed to be the main reason for "denture sore mouth" (Bastiaan, 1976), and tissue hyperplasia (Cooper, 1964; Lambson &Anderson, 1966; Ralph & Stenhouse, 1970; Ettinger, 1975). Even with new dentures, ulcers may develop very fast often within few days after fitting of the denture. Thus, denture-associated ulcers are relatively common and have been observed in 5.5 % of the subjects aged 65-74 years (Axell, 1976)

In the end there seems to be many conflicting opinions on the nature of oral mucosal lesions. The principles concerning the criteria for treatment needs and preventive treatment methods have been, however, agreed by the majority of authors. Some oral mucosal lesions

may be avoided by regular examinations and adjustments of dentures, good oral and denture hygiene and wearing the dentures only during the day.

6. AIMS OF THE STUDY

The present study was designed:

1- to document the prosthetic rehabilitation among the elderly in Helsinki and to compare the subjective and objective needs for prosthetic treatment (I and II).

2- to evaluate the relationship between oral status, history of edentulousness, prosthetic factors and the degree of residual ridge resorption (RRR) (III).

3- to record the extent of oral mucosal lesions, to assess the denture and oral hygiene habits, and to evaluate the associations among these factors (IV).

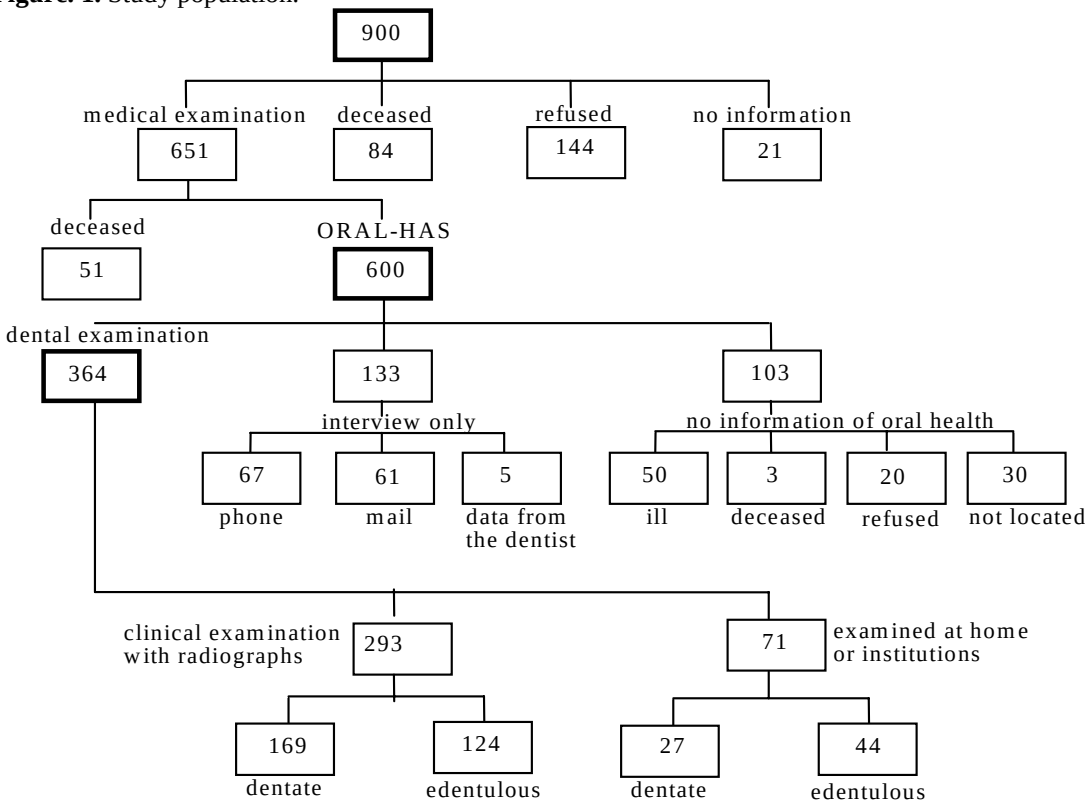
4- to re-assess prosthetic rehabilitation and evaluate its effect on the oral health of the study population over a five-year follow-up period (V).

7. SUBJECTS AND METHODS

7.1. Subjects and participation

The study population of this thesis is composed of subjects who participated in a population-based Helsinki Aging Study (HAS) between 1989-1991 (Valvanne *et al.*, 1996). From a random sample of 8035 inhabitants of Helsinki, 300 inhabitants from each age group born in 1904, 1909 and 1914, were randomly selected from the public register according to the gender and street address. Of these 900 elderly 84 had died, 11 had moved out of Helsinki and 10 were not found before the scheduled medical examination. In addition, 144 from the remaining 795 elderly refused to participate. Eventually, 651 (82%) participated in the general medical examination (Figure 1).

Figure. 1. Study population.



In 1990, the 651 subjects who underwent medical examination in public health centres in the city of Helsinki, were invited for dental and oral examination at the Institute of Dentistry, University of Helsinki. All received a letter including a questionnaire to be filled at home. Prior to the dental examination, 51 of the 651 subjects had deceased. Of the remaining 600 subjects, 364 (57%) participated in the dental examinations (Table 2). After dental examination four subjects were excluded because they had not completed all medical examinations. Therefore, the final dental study group consisted of 364 subjects. The total dropout number of subjects before the first clinical dental examination was 236. No dental data was available for 103 of these subjects: three had deceased, 50 were

institutionalised or too ill to participate, 20 refused to come for oral examination and 30 were not found or had moved from Helsinki. Only interview information was available for 133 subjects, 67 of whom were interviewed by phone, 61 by mail and five by their own dentist.

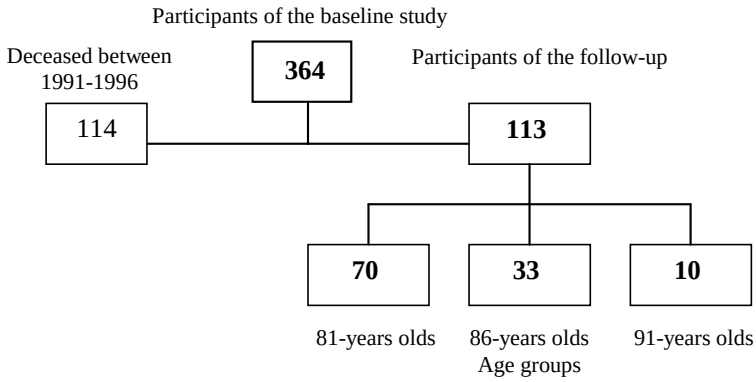
Table 2. Study population at baseline (1990-1991) and in the follow-up (1995-1996).

	Baseline examination			
Year of birth	1904	1909	1914	Total
	n (%)	n (%)	n (%)	n (%)
Men	20(22)	35(33)	48(29)	102(28)
Women	73(78)	71(67)	117(71)	262(72)
Total	93(100)	106(100)	165(100)	364(100)
	Follow-up examination			
Year of birth	1904	1909	1914	Total
	n (%)	n (%)	n (%)	n (%)
Men	4(40)	11(33)	19(28)	34(31)
Women	6(60)	22(67)	51(72)	79(69)
Total	10(100)	33(100)	70(100)	113(100)

From the original dental study population, radiographs of 185 subjects were selected (46 men and 139 women) for a separate radiographic study. The objective was to assess the factors, which may affect the rate and speed of residual ridge resorption (RRR). The subjects were selected for this part of investigation according to the following criteria: a subject should have an edentulous maxilla and/or mandible, he or she should have had participated in the baseline and follow-up clinical and radiographic examinations at the Institute of Dentistry. Eleven subjects with an edentulous maxilla and four with an edentulous mandible were later excluded because of poor quality of radiographs. Eventually, panoramic radiographs of 177 subjects (altogether 126 mandibles and 168 maxillas) were examined. Of the subjects, 124 were completely edentulous, 55 had no natural maxillary teeth, and six had edentulous mandible. All the subjects wore CDs.

All 364 subjects, who had participated in the baseline dental examinations were invited for a five-year-follow-up examination in 1996. One hundred and fourteen subjects had died during the five- year time period. Of the 250 subjects who were still available for the follow-up study, 113 participated (Figure 2).

Figure 2. Distribution of the follow-up study population



7.2. Interviews

Prior to the clinical examination, four examiners reviewed the previously mailed and pre-filled (by the patient) interview questionaries together with the patients. This questionnaire covered dental history regarding subjects' previous dental and prosthetic rehabilitation, duration of edentulousness, denture wearing habits, oral and denture hygiene habits and subjective opinion about the quality of current prostheses. Interview was done before clinical examination at the Institute of Dentistry, University of Helsinki. Seventy-one subjects who were not able to come to the oral examinations were interviewed at their homes or institutions. The questionnaire was constructed so that subject could give simple answers to questions (**Appendix 1 and 2**).

7.3. Clinical examination

7.3.1. Classification of edentulous and dentate subjects

The subjects were classified as edentulous if no natural teeth or roots were clinically present in the mouth. In all other cases she or he was categorized as dentate. Subjects wearing an overdenture with one or more abutment roots were considered dentate. Distribution of the subjects by the type of dentition is shown in **Table 3**.

Table 3. Subjects by the type of dentition.

	Men n (%)	Women n (%)	All n (%)
Natural dentition	26 (7)	42 (12)	68 (19)
Removable prosthesis in addition to natural dentition	36 (10)	91 (25)	127 (35)
Complete dentures	38 (10)	122 (33)	160 (43)
Edentulous persons, no prosthesis	3 (1)	6 (2)	9 (3)
Total	103 (28)	261 (72)	364 (100)

7.3.2. Clinical Examination

Four non-specialist faculty members of the Department of Prosthetic Dentistry carried out the oral examinations. Twenty subjects were examined twice in order to calibrate the examination procedure. The oral status was examined in a dental chair using a light, a mouth mirror, and dental and periodontal probes. Subjects' teeth were dried with an air blast before clinical examination.

7.3.3. Condition and classification of the decayed, filled and missing teeth

Number and condition of remaining teeth were examined separately for the maxilla and the mandible. Indications for extraction were recorded if a tooth was not able to be preserved. Remaining teeth were categorized according to their condition (WHO, 1987). The different categories were: (1) functional tooth, (2) tooth must be extracted because of caries, (3) tooth must be extracted because of severe periodontitis, (4) tooth must be extracted because of surgical reasons, (5) tooth replaced with a CD, (6) tooth replaced with a removable partial denture with metallic framework (MRPD), (7) tooth replaced with an acrylic removable partial denture (ARPD), (8) tooth replaced with a fixed partial denture (at least one abutment tooth with one pontic), (9) tooth replaced with a crown, (10) tooth missing and not replaced, (11) tooth not replace but should be replaced according to the patient.

Coronal caries and previous caries therapy were assessed tooth by tooth and categorized in six groups: (1) intact tooth, (2) not filled, decayed, (3) filled, sound, (4) filled, decayed, (5) fixed crown, sound abutment, (6) fixed crown, decayed abutment. Community Periodontal Index of Treatment Needs (CPITN) was used to record the periodontal health status (WHO, 1987): CPI 0= healthy periodontal tissues, CPI 1= bleeding on probing, CPI2= calculus and/or overhanging restoration margins, CPI3= 4-5 mm deep periodontal pockets, CPI4= at least one periodontal pocket => 6mm.

The presence of root caries was recorded using the Root Caries Index, RCI (Katz, 1980). All root surfaces with gingival recession of one millimeter or more were categorized as exposed and their status was recorded using classification of De Paola *et al.* (1989). Frank cavitations and secondary caries lesions on these surfaces were considered as root caries.

7.3.4. Adequacy of prosthetic rehabilitation and needs for prosthetic treatment

To assess the quality of current prosthetic rehabilitation, the elderly were first classified either edentulous (n=168) without any teeth or roots, or dentate if they had one or more natural teeth or roots remaining (n=196). The main reason for tooth loss was categorized in one of the four groups: (1) caries, (2) periodontitis, (3) malocclusion, or (4) trauma. The prosthetic rehabilitation of totally edentulous subjects was classified as adequate if both maxillary and mandible CDs had been used regularly during the last six months (WHO, 1987). In other cases the rehabilitation was considered inadequate. Rehabilitation of reduced natural dentition was categorized as adequate if either at least upper and lower anteriors and premolars were remaining and functional. No missing teeth between the second premolars in the maxilla or in the mandible should have been replaced with fixed or removable prosthesis. Otherwise the rehabilitation was considered inadequate. Hence, prosthetic rehabilitation was needed if: (1) one or both jaws were edentulous and no CDs had been used over the last six months, (2) one tooth between canines or two adjacent teeth in premolar and molar areas were missing (3) there were less than ten teeth in one jaw, (4) a dentate subject wearing a RPD had an additional missing tooth or teeth.

Of the basic study population, 144 totally edentulous subjects were drawn to assess the need for new CDs. The criteria described by Todd and co-workers (1982) and Ettinger and co-workers (1984) were followed while estimating the needs for prosthetic rehabilitation in the edentulous subjects. History of edentulousness and current dentures, use of previous dentures and the quality of the newest dentures as well as the number of dentures used were evaluated. The age of current CDs was categorized in five groups: (1) 0-5, (2) 6-10, (3) 11-20, (4) 21-30, (5) more than 30 years. Number of years elapsed since the purchase of the first CDs was categorized in six groups: (1) 0-10, (2) 11-20, (3) 21-30, (4) 31-40, (5) 41-50, and (5) more than 50 years.

CDs were clinically assessed in terms of their stability and retention using a three point rating scale: 1= good, 2= satisfactory, 3= poor. Occlusion, articulation and vertical dimension of dentures were evaluated either being good or poor. This clinical assessment was based on and modified according to studies by Kapur (1967), Rayson *et al*. (1971) and Bernier *et al*. (1984).

7.3.5. Radiological examination and assessment of RRR

Maxillary and mandibular RRR was measured to detect the possible correlations between severe resorption and history of edentulousness, use of previous dentures, use of current dentures, lesions on denture-bearing soft tissues, dental status of the opposing jaw and denture hygiene habits.

The radiographic examination consisted of a panoramic radiograph supplemented by periapical radiographs, if needed. Panoramic radiographs were made using PM 2002® (60-80 kW, 4.12 mA) radiographic apparatus (Planmeca® Oy, Finland), 3M® Trimax® T16

intensifying screens and 3M® GTU® X-ray film (3M, St.Paul, Minn., USA). All films were processed in an RP X-Omat processor (Eastman Kodak, Rochester, N.Y., USA).

In the mandible, vertical RRR was measured from five sites in each jaw. The distance from the tangential line of the most inferior points of the body of mandible and the alveolar crest were measured from both sides at a 34% and 53% full mandibular body length distance from the midline, as well as in the midline from alveolar crest to the lowest border of mandible. The most inferior points of both orbits were joined to form the reference line. Distance between this line and highest point of the maxillary alveolar crest was measured at the midline, and along the infraorbital vertical line and the zycomatic vertical line representing the sites of the first premolar and the first molar. RRR was estimated by comparing the measured vertical figures with average heights of the elderly dentate jaws. In mandible, 53% or less vertical RRR was considered slight or moderate reduction, and more than 53% reduction was classified as severe resorption. In maxilla, 15% or less vertical RRR was considered slight or moderate reduction, and more than 15% reduction was classified as severe resorption. Reduction figures were given as percentage reduction, separately for both genders and for each site of measurement.

7.3.6. Saliva collection and microbial cultivation

Paraffin-wax-stimulated whole saliva (Närhi *et al.,* 1992) was collected before the clinical examinations between 9 and 11 am. Initially, the elderly were asked to chew a one-gram standard piece of paraffin wax for one minute. After this they were allowed to swallow and the actual collection was started. The subjects continued chewing the paraffin wax and expectorated the stimulated saliva once at every minute into a test tube via a funnel. Collection was continued for five minutes. Salivary flow rate was recorded as mL/min.

Mutans streptococci, lactobacilli and yeast counts were determined by using commercial chair-side kits (SM strip-mutans for mutans streptococci, Dentocult for lactobacilli, and Oricult N for yeasts; Orion Diagnostica, Espoo, Finland).

7.3.7. Evaluation of the oral mucosa

The oral mucosa was examined and all changes were recorded according to the modified WHO criteria (Kramer *et al.,* 1980). Mucosal lesions related to the dentures were registered separately.
Lesions were classified both according to their location: (1) buccal mucosa, (2) tongue and floor of the mouth, (3) lips; or by their type: (1) inflammation limited under the prosthesis, (2) ulceration(s), (3) chronic inflammation with papillary hyperplasia, (4) chronic inflammation with fibrous hyperplasia, (5) angular cheilitis.

7.4. Statistical analysis

Statistical analyses used in the original articles were carried out by the StatView^{+TM} Graphics program (BrainPower, Inc., 24009 Ventura Blvd., Suite 250, Calabasas, CA 91302, USA) and SPSS/PC+ Advanced Statistics software (version 5.0, SPSS Inc., Chicago, Ill., USA). In addition to descriptive statistics, following tests were used:

(1) Contingency table analysis was used to compare categorized variables. Differences between two distributions were tested with Chi-squared test. Differences at 5% level were accepted as significant (II, IV).

(2) The Mann-Whitney U test was used to examine the difference in duration of edentulousness between men and women.

(3) The self estimated CD function and denture quality and subjects' age and denture age were correlated using Spearman rank correlation analysis. The number of oral mucosal lesions and medications used daily were also correlated with Spearman rank correlation analysis (II, IV).

(4) Multiple regression analysis was performed to explain the presence or absence of oral mucosal lesions by various denture hygiene variables (III).

(5) Linear regression analysis was performed to study whether the percentage reduction in the residual ridge was related to any prosthetic factors, with adjustment for confounding factors (III).

(6) Logistic regression analysis was fitted to study the association of severe RRR in terms of history of edentulousness and denture wearing, the condition of current dentures and denture bearing soft tissues, dental status of opposing jaw, and subjects' denture hygiene habits. Differences at the 5% level were accepted as significant. Logistic regression analysis was also used to find out the possible association between prosthetic status, tooth loss and five-year caries increment (III, V).

(7) Differences in various oral health variables related to different types of dentitions were evaluated using an ANOVA fitted with Fischer’s PLSD post hoc test. Differences in mean values between two distributions were evaluated with t-test (V).

8. RESULTS

8.1. Retained and missing teeth and causes for the loss of teeth (Paper I)

Of the whole study population, more than half (54%), 135 women and 61 men were classified as dentate (1-32 natural teeth left). They had 47% of their theoretical maximum number of natural teeth left (range 1-32, mean 13.7, 13.2 excluding third molars). Thirty-nine per cent of the maxillary teeth were remaining (mean 5.5) and the corresponding figure in the mandible was 55% (mean 7.8). Of the remaining teeth, 13% was fitted with prosthetic crowns and 5% had an indication for extraction.

One hundred and ninety-six partly dentate subjects had altogether 743 missing teeth, including the third molars (I; Fig. 2). Fifty-five subjects had 81 maxillary and 63 mandibular missing teeth in the area between the second premolars. Twenty-seven subjects had open tooth site(s) only in the maxilla, 19 only in the mandible and 9 subjects in both jaws. Distribution of the missing teeth in the dental arches is shown in Table 4.

Table 4. Distribution of maxillary and mandibular open tooth sites in dentate subjects.

MAXILLA

	No. of teeth (%)			
	anterior teeth n (%)	premolars n (%)	molars all n (%)	n (%)
women (n=135)	22 (52)	41 (49)	379 (66)	442 (64)
men (n=61)	20 (48)	43 (51)	191 (34)	254 (36)
total	44 (100)	84 (100)	570 (100)	696 (100)

MANDIBLE

	anterior teeth n (%)	premolars n (%)	molars all n (%)	n (%)
women	18 (46)	73 (67)	495 (68)	586 (68)
men	21 (54)	36 (33)	220 (32)	277 (32)
total	39 (100)	109 (100)	725 (100)	863 (100)

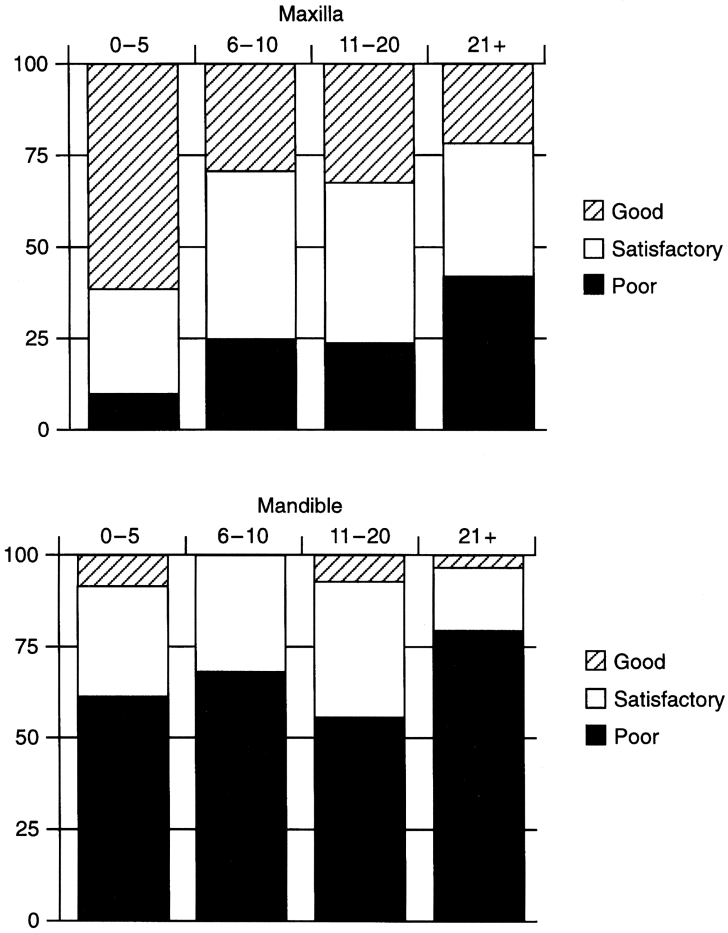
According to the interview data, 53% of all subjects had lost their natural teeth because of caries, and 13% because of periodontitis. Of the subjects, 31% did not remember the cause for removal, while 2% had lost their teeth following an accident and 1% due to cosmetic reasons. Thus, caries and periodontitis together represented more than half of the known causes for tooth loss (66%). The five-year follow-up showed that loss of natural teeth was clearly connected to the male gender and use of any kind of RPD at baseline.

8.2. Prosthetic rehabilitation of the edentulous elderly and adequacy of rehabilitation (Papers I, II)

Forty-six per cent of the 364 elderly, 40% of men and 48% of women were edentulous. A set of CDs was worn by 94% of the edentulous. Seven edentulous subjects did not have any kind of prostheses, three had only maxillary CD, and one had maxillary overdenture with two supporting roots, and was classified as dentate. The time of the provision of the first CDs varied greatly within the limits of 0 - >50 years (Paper I; Fig. 3). Of the dentures, 8% were issued more than 50 years ago. Twenty-seven per cent of the subjects did not remember the time of insertion. Age of the last set of CDs varied from less than one year to over 30 years. Most of the dentures, 75%, were less than 20 years old. In a subgroup of 144 edentulous CD wearers one quarter of the dentures were more than 20-years old (Paper II). Eighty-seven percent of all maxillary and 88% of the mandibular CDs were considered sound. The existing damages in the dentures were usually minor (small base fractures, fractured pieces of acrylic resin or a lost single tooth). The older the denture the more faults it had.

Stability of the maxillary CDs was good in 38%, satisfactory in 36% and poor in 26% of the dentures; in mandible, the figures were 19%, 31%, and 50%, respectively (Paper II; Fig. 1). In the maxilla, the number of dentures with good stability ranged from 58% of the newest denture group to 21% in the oldest dentures. The worsening of the stability with the increasing age of the denture was statistically highly significant in the maxilla ($p<0.001$). A total of 38% of maxillary CDs had good retention, 38% had satisfactory and 24 had poor retention. Of mandibular CDs only 6% had good retention, 29 satisfactory and 65% had poor retention (Paper II; Fig. 2). In the maxilla, there was a highly significant correlation between the poor retention and the age of the denture ($p< 0.001$) (**Figure 3**). Centric relation in occlusion, articulation and vertical dimension of occlusion became less satisfactory with the increasing age of the dentures (Paper II; Fig. 4). Occlusion was good or satisfactory in 53% and articulation in 43% of the dentures. Vertical dimension was considered good or satisfactory in 49%, too low in 44% and too high in 7%.

Figure 3. Distribution of complete dentures by their age and retention.



According to the WHO criteria (1987) and those by Todd and co-workers (1982), 94% of all edentulous in the whole study group had objectively adequate and 6% had inadequate prosthetic rehabilitation (I), whereas all of those 144 subjects drawn from basic study group for the comprehensive CD analysis had adequate rehabilitation (II). Among this group, however, as many as 84% of the subjects had inadequate prosthetic rehabilitation based on clinical evaluation of both the mechanical and functional condition of the dentures. No significant differences between sexes or among the age groups were found. The need for replacement increased with the age of the denture. In the maxilla, 10% of the 0-5-year-old dentures and 53% of the 21-30 year-old dentures needed replacement, and in the mandible the figures were 15% and 45%, respectively.

8.3. Prosthetic rehabilitation of the dentate elderly and adequacy of rehabilitation (Paper I)

Forty-five percent of the 196 dentate subjects, 88 subjects, had 214 maxillary and 132 mandibular crowns, including the FPD abutments. Eighteen per cent of the dentate had 44

maxillary and 24 mandibular FPDs. Of the abutments, 30% were decayed. Women had most of the fixed prosthesis (75%). All age groups had about the same percentual amount of FPDs, but the younger subjects had more crowns than the older. No difference between the maxilla and mandible was found.

Of the dentate subjects, 25% had some kind of combination of fixed and removable prostheses, whereas 14% had no prosthesis (I; Table 2). All these prosthetic combinations were without precision attachments. Thirty-four per cent wore ARPD, 19% MRPD, and 38% had a CD in one jaw (34% in maxilla and 4% in mandible).

Among the dentate subjects, 16% of all lost teeth were not replaced, 5% of which was considered to need immediate prosthetic therapy (Paper I; Fig. 2). Twenty-one per cent of the empty spaces were located in the anterior and premolar region. Second premolar was the most frequently missing tooth. Among the partly dentate subjects, 37% of the missing teeth were replaced with prostheses. Prosthetic status of remaining teeth is shown in Figure 4.

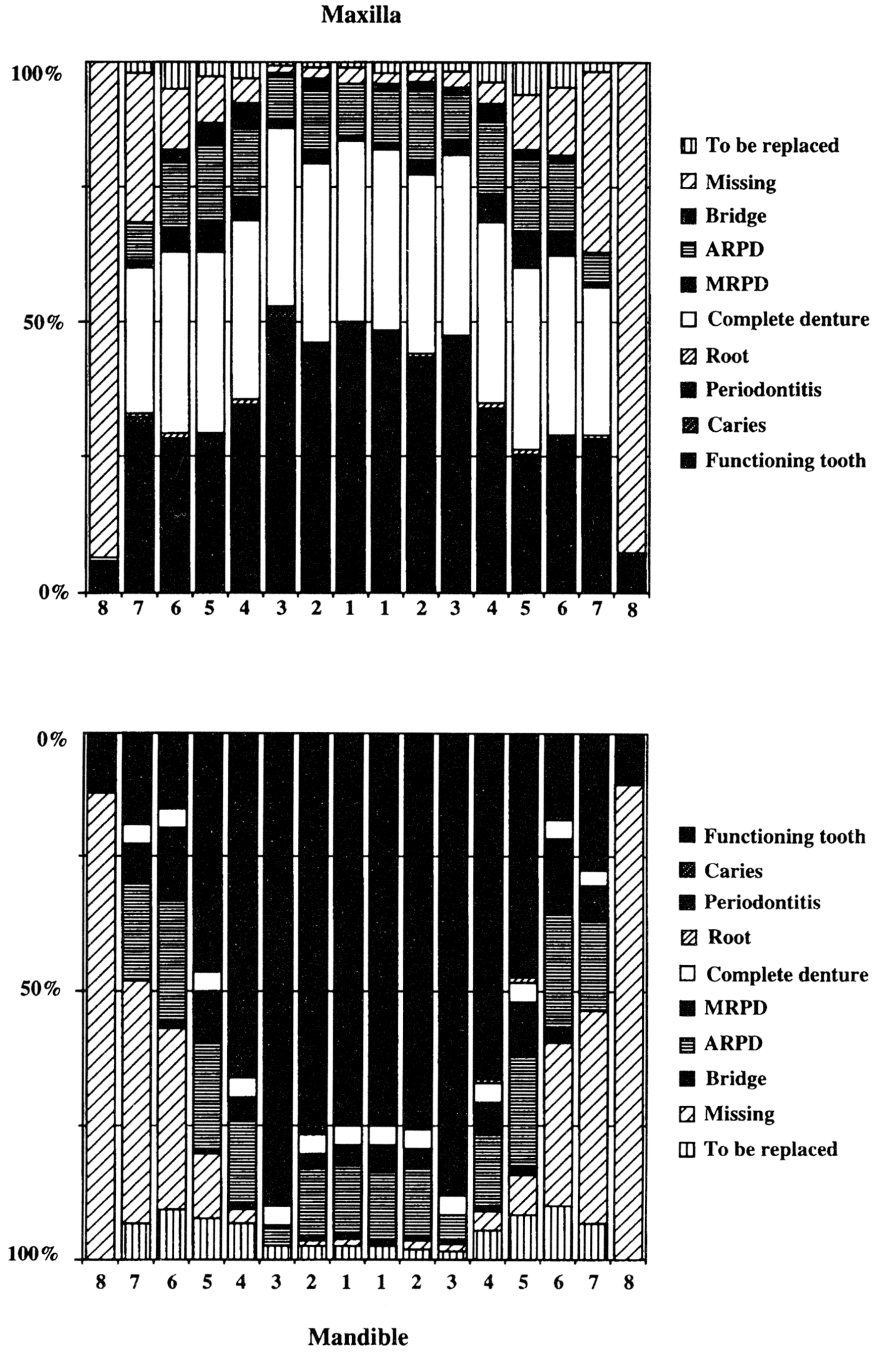
Of the dentate subjects, 30% was considered to have inadequate rehabilitation in the maxillary anterior and premolar or molar region and 51% in the same regions in the mandible. Ten per cent of rehabilitations were considered inadequate because of too few remaining teeth (less than ten/jaw), and 27% had missing tooth or teeth between the second premolars. Thus, finally only 37% of the dentate subjects were considered to have an adequate prosthetic rehabilitation. The function of crowns and FPDs was found to be adequate in all cases.

8.4. Subjective need for further prosthetic treatment (Papers I, II)

Of the subjects who participated in comprehensive CD analysis, 69% found their dentures good or satisfactory and 10% found them poor. Of the subjects, 21% were not able to give an opinion. Men (51%), more often than women (42%) found their dentures good. Based on examiners' experience, clinical examination of the patient and dentures and discussion with the patient, 25% of the maxillary CDs and 27% of mandibular dentures needed replacement. The need for replacement increased with the age of a denture. Twenty-seven per cent of the elderly with crowns or FPDs replied to the questions concerning subjective satisfaction of the rehabilitation. Eighty-eight per-cent of those found the artificial crowns and FPDs good while the rest found them satisfactory. The appearance of the artificial teeth was better in 4%, equally good in 83% and worse than the appearance of natural teeth in 13% of the elderly.

Of the elderly with FPDs, 83% considered biting and chewing easy, 13% found it satisfactory and 4% found it difficult. Food was packing easily between the crowns and under the FPDs in 46% of the subjects, and 21% had difficulties with cleaning the fixed prosthesis.

Figure 4. Prosthetic status of remaining teeth.



8.5. Residual ridge resorption (Paper III)

Women had been edentulous ten years longer than men. No difference of duration of edentulousness (median 21-30) was found between maxilla and mandible. The percentual (percentage) RRR was significantly related to denture quality in both jaws (Paper IV; Table 3: $p<0.05$ for the mandible, $p<0.01$ for the maxilla). In the maxilla, significant positive correlations were found between the percentage of RRR and previous use of RPDs ($p<0.05$), few dentures worn ($p<0.05$), and the presence of flabby ridge ($p<0.05$). No association was found between percentual RRR, duration of edentulousness and dental status of the opposing jaw.

In the mandible, the number of CDs worn and previous use of maxillary RPD were significant factors for severe resorption (Paper IV; Table 3). Flabby ridge was mostly related to severely resorbed maxillas, and the number of denture related mucosal lesions was smaller in severely resorbed maxilla than in the slightly or moderately resorbed maxilla. Additional associations between severe RRR and other variables were not found.

8.6. Oral mucosa and denture hygiene habits (Paper IV)

Thirty-eight per cent of the elderly had one or more oral mucosal lesions. Mucosal lesions were found in 51% of the CD-wearers and in 31% of the partly dentate subjects with removable prostheses. The most common mucosal lesions not directly related with dentures were coated changes of the tongue (7%), angular cheilitis (6%) and varicose veins (4%). Besides angular cheilitis, which was more common in women than in men (8% and 1%, $p<0.05$), no significant differences between genders were found. The prevalence of lesions was not significantly different among the elderly in different age groups.

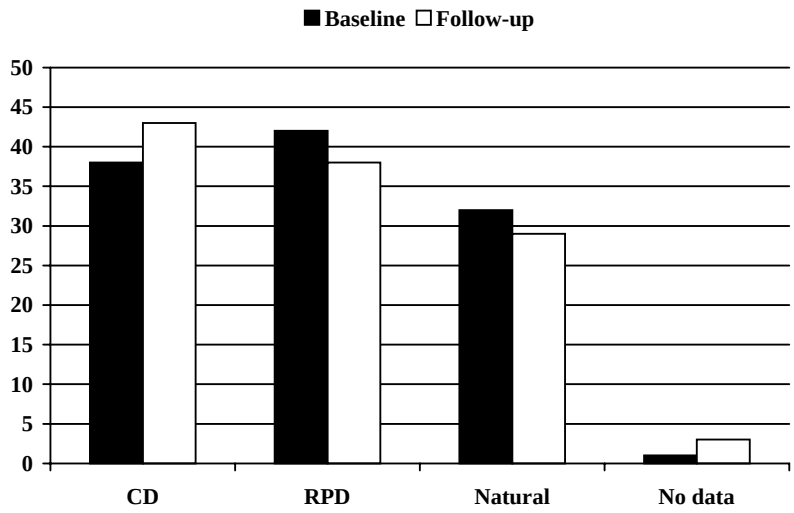
Majority of the mucosal lesions were related to removable dentures, inflammation being the commonest finding. Inflammation was more common in women than in men (29% and 14%, $p<0.05$). Most of the lesions were related to maxillary dentures. Of the CD wearers, 96% and 98% of those with an RPD reported cleaning their dentures daily, whereas 86% of CD wearers and 92% of those with an RPD reported cleaning also the denture bearing mucosa. Negative correlation was found between the presence of oral mucosal lesions and cleaning of the oral mucosa (r_s= -x, $p<0.05$). There was a positive correlation between the number of medicines used daily and the number of oral mucosal lesions (r_S = 0.23, $p<0.05$).

8.7. Five-year follow-up (Paper V)

Sixty-one percent (n=69) of the subjects in the follow-up examination had 1 to 32 existing natural teeth. Of these subjects, 49% had lost one to six teeth since the baseline examination. As a result of this, five new subjects became edentulous during the follow-up. Male gender and use of any type of RPD correlated with the number of lost teeth (Paper V; Table 2).

The prosthetic status of 30 partly dentate subjects (43%) had changed by the time of the follow-up examination. In the follow-up, 52% of the dentate had a removable prosthesis; 35% of the subjects had ARPD that was also the most frequent form of prosthetic rehabilitation. The change in prosthetic rehabilitation is shown in Figure 5.

Figure 5. Number of subjects with complete dentures (CD), removable partial dentures (RPD) or natural dentition among the participants of the baseline and the follow-up studies (n=113).



There was a positive correlation between wearing of an RPD, increment of root caries and poor periodontal health: subjects with natural dentition had three times more periodontally healthy sextants than RPD wearers (26% and 9% respectively).

Subjects with natural dentition had also a lower count of microorganisms than those with any kind of removable dental prosthesis ($p<0.01$ and $p<0.05$).

9. DISCUSSION

9.1. Subjects and methods

In Finland, the percentage of elderly women is about 66% at the population level, which is higher than in other Scandinavian countries (Ainamo & Österberg, 1992). Even though female representation in the population studied in this thesis was higher than this, the overall distribution, 72% women and 28% men, is similar to the demographic figures describing the whole Finnish population. In Helsinki, 14% of the inhabitants have a university degree compared to 5% in the whole Finland. Thus, the original HAS-group, drawn from the Helsinki population census in 1989, represented the best-educated part of the elderly Finns (Vehkalahti *et al.,* 1996).

From the comprehensive medical study group, 63% participated in the Oral-HAS, which is satisfactory considering the high age of our subjects. Problems related to mobility, dependency on help and general tiredness have shown to limit utilization of dental services (Avlund *et al.,* 2001), a fact that most probably affects our study in a similar way. Thus, a thorough medical examination carried out before the dental study might have reduced the participation rate. The elderly with no medically compromising diagnoses and those with relatively good physical condition and living near the University dental clinic tended to participate more actively than their counterparts (Vehkalahti *et al.,* 1996). In 86% of the subjects, faculty members of the department were able to carry out the clinical examination at the Institute of Dentistry. The 14% of the subjects who were too ill or tired to come to the Institute of Dentistry were examined at their homes or hospitals.

To standardise the clinical examination and recording procedure, four dentists examined twenty subjects twice. In spite of this precautionary measure, the collected data may have been influenced by examiners' interpretations. Naturally, this applies to both the assessment of the condition and function of the existing prosthetic treatments, but may have had the strongest impact on the results regarding the needs for prosthetic treatment, based on examiner’s subjective evaluation.

The collection of proper interview information was occasionally problematic. The elderly had often difficulties to recall the history of their dental treatment. In the age groups of 75-year olds, 80-year olds and 85-year olds the prevalence of dementia was 5 %, 13% and 27%, respectively (Juva *et al.,* 1993). Even without dementia, the advanced age alone can make it difficult to recall the earlier events in life. This must be kept in mind in the interpretation of interview data.

9.2. Loss of natural teeth

In Finland, a clear increase in the number of subjects acquiring dentures was seen in the 1950's and 1970's. Social changes in the country may partly explain this sudden need for new dentures. During the World War II and the late 1940's and early 1950's, many necessities of life were rationed in Finland. Slowly the situation improved, and eventually even the sugar became free from rationing in 1954. This led to changes in eating habits, radically increasing the use of sugar that subsequently increased the prevalence of caries (Rytömaa *et al.,* 1980). The free of charge dental services for young children could not prevent the effects of these undesirable life style changes.

In the early 1950's, the number of dentists was still low, in many areas one dentist to 10 000 citizens (Calonius 2000). At the same time the focus-infection philosophy in dentistry favoured extractions, which was the only rational treatment in many emergencies. This approach was abandoned during 1970's and 1980's, as the prevalence of caries decreased and the number of dental practitioners increased. By the 1990's, the dentist-population ratio was already as good as 1:800. In spite of this favourable development, edentulousness in the elderly continued to increase even in the Southern Finland over the 1970's and 1980's (Ainamo & Murtomaa, 1991). Ironically, the improved dental health services in the cities could partly be blamed for this development. As a consequence of the easier availability of dentists' services the extraction of teeth increased. Caries turned out to be the most important indication for the loss of teeth also in the study population (53%) of this thesis (Paper I). This extraction focused treatment philosophy led to increased need for partial and complete dentures. Paper I demonstrates a clear increase in the number of first time denture wearers in the 1950's and 1970's.

9.3. Prosthetic rehabilitation with removable prostheses

Forty-six per cent of the subjects in this study (40% of the men and 48% of the women) were totally edentulous. The difference in edentulousness between genders was smaller than in previous studies (Ranta 1987; Tervonen 1988; Nyman 1990), and smaller in Helsinki than in other parts of Finland. This is comparable with the findings of Vehkalahti and co-workers (1991), who reported that edentulousness in the population of over 30 years of age was rarer (18-30%) in the industrialized Southern part of Finland than in other parts of the country (28-47%).

According to frequently used criteria described by Todd and co-workers (1982), 94% of the edentulous subjects in present study had adequate prosthetic rehabilitation. Rehabilitation rates for men and women were the same for all age groups. In their study Ranta and co-workers (1985) recorded a similar percentage of adequate rehabilitation (89%) in Southern Finland. Generally, the large age variation in previously published articles makes the comparison of rehabilitation rates difficult. However, the reported figures seem to run in the same direction. Rise and Helöe (1978) reported a prosthetic rehabilitation rate of 83% in the Northern Norway among 64-79 years old subjects. In Denmark, the rate was 86% among the 65-year old and older subjects (Grabowski & Bertman 1975) and 79% in whole Finland (Ranta *et al.,* 1985). However, Ekelund (1983) reported a clearly lower rehabilitation rate (55%) among the residents of municipal old people's homes in Finland.

Against this background it is no surprise that a set of CDs was noted to be the most frequent form of prosthetic rehabilitation both in women and men (Paper I). Many of these dentures were rather old, about 70% of the subjects wore CDs issued two to twenty years ago, although some dentures might have been even older since many subjects had difficulties to recall their dental history. The prosthetic rehabilitation of 144 subjects wearing both maxillary and mandible CDs were evaluated as a separate group. The results regarding the stability, retention, centric relation/occlusion, articulation, and vertical dimension of occlusion with the dentures revealed that these features impaired with the age of the dentures support the findings reported by Hoad-Reddick (1989). In present study, the lack of retention was reported as the main dental problem especially among those who had worn CDs for a long time. Poor retention and pain generated by the mandibular CD have been reported to be the most frequent causes triggering adjustment visits among CD wearers (Mäkilä, 1974; Kalk & de Baat, 1990; Lechner *et al.,*1995; Närhi *et al.,* 1997).

To solve these complete denture related functional problems an implant-supported overdenture can, in well-selected cases, be the right and sometimes the most suitable form of prosthetic rehabilitation (Tarlow, 1998). The common assumption that poor oral health is inevitable in older age, has sometimes lured dentists to classify geriatric patients as unsuccessful candidates for dental rehabilitation (Haug, 1997). Naturally, in the process of choosing suitable patients for the dental implant treatment it is imperative to take numerous age-related medical, physiological, anatomical, psychological and socio-economical problems into the consideration (Anttila *et al.,* 2001; Nisizaki, 2003; Lindquist & Ettinger, 2003). When evaluating the need for this type of treatment, it is important to keep in mind that decreased masticatory efficiency has shown to cause changes in the food choice with a reduction in the dietary fibre intake and consumption of fruits and vegetables leading to nutritional deficiencies (Walls *et al.,* 2000; Marshall *et al.,* 2002). Thus, significantly improved retention created by using osteointegrated implants may be crucial for individual's wellbeing. Patient's age alone is never a restricting factor for implant therapy (Salonen, 1994; Oikarinen *et al.,* 1995; Garg *et al.,* 1997).

From the dentist's point of view, CDs have usually been worn too long. The older the dentures the greater the number of faults they have (Bergman & Carlsson, 1985). This finding was also confirmed in our study. However, there seems to be often a disagreement between dentists' professional opinion about the dentures and the patients' subjective feelings (Tervonen, 1988; de Baat *et al.,* 1997). The longer the dentures have been worn, the better they are accepted and tolerated by the patients (Todd & Lader, 1988; Müller *et al.,* 1994). According to Mäkilä (1974), 71% of the elderly aged 65 years and over, had some adaptation problems after one year wearing of new CDs. Todd and Lader (1988) found that those subjects who had used their dentures less than five years experienced more problems with their dentures than those whose dentures were 20 years old or older. In addition to this, the older denture wearers seem to cope well with their dentures and are often very reluctant to get new ones (Müller *et al.,* 1994). Already in 1961, Langer and co-workers reported that the patients' satisfaction with CDs was closely related to the successful use of the mandibular denture and their ability to chew, but no correlation was found between patients' satisfaction and clinical fit of the dentures. It is clear that the dentist's subjective treatment decision can be highly influenced by multiple factors like sex, age, environment and complementary studies of the dentist (Rantanen, 1976; Kronstrom *et al.,*, 2000; Paper II). Thus, subjective evaluation by one dentist alone can be considered to be fairly unreliable (Rayson *et al.,* 1971). Decision either to repair or replace the old dentures should not be based only on a dentist's subjective opinion and clinical examination. Consulting the patient, and taking into consideration his or her expectations should be a crucial part of treatment planning (Kalk & de Baat, 1990).

Of the subjects, 69% had visited their dentist last time more than six years ago (Ainamo *et al.,* 1993). Also in the United Kingdom, only 5% of the adults, aged 75 years and over and wearing CDs were planning to visit their dentist, although 34% of the dentures were more than 20 years old (Todd & Lader, 1988). The infrequent use of dental health services and thus inadequate maintenance of CDs (Cabot & Roberts, 1984) can explain some of the denture-related problems also in this study population.

The results regarding the replacement needs of the CDs were somewhat contradictory (Papers I and II). According to the WHO method, 100% of the elderly in our comprehensive CD study population had satisfactory rehabilitation. Based on other evaluation criteria, 25% to 74% of the maxillary and 27% to 84% of mandibular dentures

needed replacement (Paper II). Similar conflicting figures have been reported earlier (Ritchie, 1973; Mäkilä, 1979; Hoad-Reddick, 1989).

At the time of the follow-up examination, loss of the last natural teeth had created five new CD wearers. This is not surprising considering the high number of acrylic partial dentures in the baseline and quite many elderly subjects with extremely shortened dentitions with only one or two natural teeth.

In 1987, 72% of the 75-year old and older Finns used some kind of removable dentures (Nyman, 1990). In the present study, 78% of all dentate elderly had an RPD or some kind of combination with FPD and RPD. This figure is higher in the home living elderly in Helsinki than in their same aged counterparts living in rural areas (Ranta *et al.*, 1987). Rather low number of new RPDs made during the follow-up period might be a consequence of the dentists' and patients' changing attitudes towards this type of treatments. This development can be seen beneficial because the results demonstrate an association between the use of any kind of removable denture and increment of root caries and poor periodontal health (Paper V). This agrees with other studies that suggest that fixed dental prosthesis deliver better overall result with less negative side effects (Budtz-Jörgensen & Isidor 1990; Jepson *et al.*, 2001). Wearers of removable denture had also a higher count of salivary microbes than the elderly with natural dentition. It is true that denture structures can support plaque retention, but the high number of mutans streptococci in the elderly is related to lack of cleaning (Närhi *et al.*, 1992) and it is quite possible that the difference in the amount of micro-organisms has its' origin in generally poor oral hygiene history.

9.4. Prosthetic rehabilitation with fixed prosthesis

Although the number of remaining teeth in the elderly in Helsinki can be considered high, the number of missing and not replaced teeth was also high. Teeth were usually missing in molar and premolar area, but surprisingly often also in the anterior parts of the dental arches (Paper I). In the present study the number of subjects retaining natural teeth was markedly higher compared to that in the study of Nyman (1990) who reported that in 1987, only 39% of the Finnish population aged from 65 to 99 years had one or more teeth, or to the Health 2002 study where 49% of the 85-year old and older men and 40% of women were dentate (Aromaa & Koskinen, 2002). On the other hand, The National Study of Dental Health in U.S. Adults (1987) found that in 1985-1986, 59% of those 65-year old and older and 51% of those aged 80 years or more, were at least partially dentate. These figures are more similar to the numbers the results.

Until recently, the prevalence of fixed prosthesis has been considerable low among the elderly populations. Especially, among those living in institutions crowns and FPDs have been very rare. In a sample of 488 inmates of old people's homes, aged 65 years and more, fixed prosthesis were found in only 3% of the elderly (Mäkilä, 1979). Two to three percent of the subjects had crowns or FPDs in the study of Tervonen (1988). In the present study, 45% of the dentate elderly in Helsinki had prosthetic crowns including the FPD abutments. This is clearly more than the corresponding figures, 11% and 4% reported in the Mini-Finland Oral Health Study (Ranta & Paunio, 1986). The percentage of FPDs (18%) in the present study is, however, rather low compared to a Swedish study of 593 elderly inhabitants (60-84-year old) in the City of Stockholm, where FPDs were found in 30% of the elderly (Marken & Hedegård, 1970). The finding that the prevalence of fixed

prosthesis was higher among women than among men agrees with the result reported by Ranta (1987).

In the present study, women had 75% of all prosthetic crowns (Paper I). Hence, it was no surprise that most of the decayed abutments were also found in women. However, because the average number of natural teeth was higher in men, they had more decayed natural teeth. In a Danish population, among those of 65 years of age and older, the mean number of decayed teeth was three (Grabowsky & Bertram, 1975). The corresponding figure, 1.5, obtained in our study, was clearly lower. The finding that the urban well-educated people take good care of their dental health (Lehtinen, 1975), and the residents in capital area use more dental health services than people in other parts of the country (Kalimo *et al.*, 1989), may explain this low figure.

9.5. Residual ridge resorption

According to this study, the duration of edentulousness seemed to have little effect on RRR after the initial resorption had taken place during the first years after the extractions (Paper IV, Table 3). The most important dental factor for RRR was the quality of dentures. Many of our subjects had been edentulous for several decades and most of the RRR had been taken place earlier in their lives. This is obviously the reason for the low interrelationship between prosthetic factors and RRR noticed in our subjects. With time, severe RRR results in the formation of the flabby ridge as the underlying bone can no longer support the soft tissues of the residual ridge. Flabby ridge was frequent in many of our subjects and its' presence was clearly associated with RRR (Paper IV, Table 3).

9.6. Oral mucosa and denture hygiene

The dental status of the elderly has often been found to be poor and the oral hygiene seems to deteriorate with the increasing age (Richie, 1973; Homan *et al.*, 1988; Angelillo *et al.*, 1990; Hoad-Reddick *et al.*, 1990). This situation is not dangerous only from dental and periodontal health point of view. Cumulating data is demonstrating that poor oral health has also a negative impact on some systemic health problems, especially on type 2 diabetes and aspiration pneumonia (Taylor *et al*. 2000). Despite the fact that almost all the subjects in my study reported that they clean their dentures every day, their efforts had not been successful. Brushing turned out to be the most popular denture cleaning method. Seventy-four per cent of the elderly brushed their dentures and some used other cleaning methods as well. Polyzois (1983) has reported similar figures. Hoad-Reddick *et al.* (1990) found that 90% of the elderly with clean dentures and 77% of those with dirty dentures reported that they cleaned their dentures daily. This confirms the fact that daily cleaning per se does not necessarily lead in good results if the cleaning methods are not effective. These figures are very close to the figures of the present study.

Active brushing and cleaning of all oral soft tissues has found to be very important for the maintenance of oral soft tissue health and control of mucosal inflammation (Budtz-Jörgensen, 1979). Bloem and co-workers (1984) verified this connection by measuring the reduction of inflammation as a result of tissue brushing. A statistically significant improvement was found in the oral mucosal health among totally edentulous patients who followed a home care regimen of tissue bushing for 60 days. However, in Paper III the brushing frequency showed a negative correlation with the presence of soft

tissue lesions, although 86% of the edentulous denture wearers reported that they clean the denture supporting mucosa every day.

Traditionally, brushing the denture with a cleansing agent has been a recommended method for home care. Denture cleaning and understanding its importance can be difficult for many older people. Therefore, recommended method of cleaning should be easy to carry out. Spiechowicz and co-workers (1990) evaluated the growth of *Candida albicans* on the surface of acrylic resin disks, and found that storing the disks in open air caused a loss of viability and death of *Candida albicans*. Rinsing the dentures in the evening and keeping them overnight in the open air can indeed be the easiest way to carry out "disinfection" (Stafford *et al.*, 1986). However, 10 minute soaking in chemical disinfection solutions like 4% chlorhexidine gluconate, 1% sodium hypochlorite and Amosane solution (alkaline peroxide) have proved to be an effective method as well (Pavarina *et al.* 2003).

The previously reported percentages of oral mucosal lesions have varied between 52% and 59% (Manderson & Ettinger, 1975; Smith & Sheiham, 1979; Vigild, 1987; MacEntee & Scully, 1988; Jorge *et al.*, 1991). These are slightly higher figures than the 46% in my study where the age of the subjects alone seemed to have no significant effect on the prevalence of mucosal lesions. Hoad-Reddick (1989) and MacEntee and co-workers (1988) have published similar results. When examining the home living population in the district of Cheshire, England, they found that 41% had some oral mucosal lesion. The prevalence of lesions was highest, about 66 %, among the subjects living alone in the community with no assistance.

Tumours were not found in this study (Paper III). This is different from the studies using biopsy specimens from the oral cavity, which have shown that 15-25% of the oral lesions are usually tumours (Bhaskar, 1968; Weir *et al.*, 1987). Moreover, in his study of oral health of institutionalised seniors Mäkilä (1977d) found that the figure for benign tumours or tumour like lesions was 8%. Traumatic ulcers usually develop 1-2 days after issuing new dentures. The high age of the dentures in Paper III study group indicated that the prevalence of ulcers would not be very high. This was indeed the case: ulcers not related to dentures were found in 2% of the subjects and denture-related traumatic ulcers in 4% of the subjects respectively. Axell (1976) has published a slightly higher figure: ulcers were observed in 6% of the 65-74-year old subjects.

Prevalence of soft tissue hyperplasia was highest (6 %) among the 75-year olds decreasing with the increasing age of the subjects (Paper III). The total percentage of subjects with hyperplasia was 5%, which is notably lower than the 14% reported by Ettinger (1975). The chances for finding angularis cheilitis is increased, about three-fold, in denture wearers and almost doubled in men (MacEntee *et al.*, 1998). This lesion is multifactorial in origin and is connected with several predisposing factors like large intake of carbohydrates, avitaminosis, and anaemia. Ten percent of the elderly in the present study had angular cheilitis, which is less than half of what have been reported in institutionalised elderly in Finland (Mäkilä, 1977a).

A connection between high amount of yeasts in the oral flora and denture-induced stomatitis has been reported. Correlation between the high count of salivary yeasts, mucosal lesions and the use of CDs has also been reported earlier among the participants of HAS (Närhi *et al.*, 1993). The prevalence of denture induced stomatitis (22%) in the present study population is slightly higher than the 17% documented by Richie (1973), and

remarkable lower than 42% reported by MacEntee and Scully (1988), but agreed with the figures reported by Vigild (1987).

Commercial denture adhesives are well accepted and a widely used method to improve the retention and stability of CDs (Coates, 1995). Five percent of our subjects used the adhesives daily and 8% occasionally. Continuing use of these agents might, however, have some disadvantages. Denture adhesives have been found to support the growth of *C. albicans* (Stafford & Russell, 1971), which is known to be the most common yeast related to denture stomatitis (Budtz-Jorgensen, 1974).

Although there seem to be many conflicting opinions about the nature of the oral lesions, the principles concerning preventive treatments and the need for care among the elderly is agreed by the majority of the authors. Improving denture cleanliness, wearing the dentures only by day, and brushing the denture covering tissue daily with soft brush may prevent oral pathological lesions.

9.7. Five-year follow-up

During the 5-year follow-up half of the dentate participants of this study lost only few teeth (1.1±1.5). Forty percent of dentate subjects had had some changes in their prosthetic status: 25% received a new prosthesis (RPD or FPD) and 15% lost their prostheses, which were not replaced. Only 4% became totally edentulous.

A clear tendency towards provisional treatment was seen as acrylic RPDs were more frequently provided than RPDs with metallic framework. In general, all kind of RPDs seem to increase the risk of denture abutment teeth for caries and periodontal diseases (Jepson *et al.*, 2001; Zlataric *et al.*, 2002). This was also clearly seen in the follow-up study as wearing an RPD was associated with the increment in root caries and poor periodontal health. Furthermore, wearing of any kind of RPD increased the risk for tooth loss. The elderly with removable dentures had also higher numbers of salivary microorganisms than those with natural dentition. The number of elderly with provisional RPDs can be considered high: 75% of my subjects wore an acrylic RPD. This is mainly due to financial reasons. Age itself did not limit practitioners' and patients' treatment decisions regarding fixed prosthodontics: 16% of dentate elderly were rehabilitated with fixed prostheses during the follow-up. Consequently, the prosthetic treatments completed during the follow-up were mainly replacements of old RPDs. The present study clearly demonstrated that aging as such does not increase the risk for tooth loss. It also clearly demonstrated that the use of RPDs is associated with several oral diseases and impaired oral conditions. Thus, it may be concluded that FPDs should be favoured also in elderly patients' prosthetic rehabilitation.

10. SUMMARY AND CONCLUSIONS

In the Western societies, open teeth spaces on the visible anterior part of dental arch are considered to be socially unacceptable and degrading. Reduced dentition has been believed to modify food intake, lead to vitamin deficiency or even malnutrition.

As a part of the population-based medical Helsinki Aging Study (HAS), the oral and dental health and dental hygiene habits of 364 old elderly, born in 1904, 1909 and 1914 and living in Helsinki, was examined in 1990 and 1991. The main objective of this study was to document the current status of and changes in prosthetic rehabilitation among the elderly in Helsinki during a five-year follow-up. The study attempted to compare the existing subjective and objective needs for further prosthetic treatment. Background factors affecting the existing prosthetic status were also examined. The influence of prosthetic factors on RRR was evaluated in a subgroup of edentulous CD wearers. Presence of oral mucosal lesions and their association with removable prostheses was recorded. Finally, the five-year follow-up attempted to study associations between prosthetic rehabilitation and oral health.

Of the 364 participants 196 were dentate. When the third molars were excluded the mean number of teeth among these 196 subjects was 13.2 excluding third molars. Fourteen percent of the dentate subjects did not have any kind of prosthesis. Seventy-four percent of all the participants had removable dentures and 24% had fixed prosthesis. By the follow-up examination prosthetic status had changed in 43% of the dentate subjects, acrylic removable partial denture being the most worn type of denture. The fixed prosthesis was more common in women than in men. Younger age groups had most of the artificial crowns.

Among the dentate subjects, 84% of the missing teeth were replaced with removable or fixed prostheses. In spite of this further 5% of were judged to need additional rehabilitation.

Of the subjects, 46% were totally edentulous. Over the follow-up period, edentulousness increased only marginally, there were only five new CD subjects. CD in both jaws were worn by 94% of the edentulous subjects, only maxillary CD was worn by 2% of the edentulous subjects and 4% did not wear denture at all. Only one subject had an implant-supported overdenture in the mandible. Twenty-five percent of the dentures turned out to be more than twenty years old.

As a part of this study, a subgroup of 144 subjects wearing a full set of CDs were examined separately. The age, condition, and functional properties of the dentures were assessed. When the functional properties were compared with the age of the dentures, it was found out that all properties, except articulation, worsened with the increasing age of the dentures. As expected, mandibular dentures more often than maxillary dentures, had poor retention. Only 6% of the mandibular dentures had good retention compared to the 38% in the maxilla. Almost 90% of all CDs were sound. Only minor mechanical faults were found. Hence, unsatisfactory functional properties were the main objective indication for denture replacement needs: 84% percent of the subjects needed new dentures because of functional deficiencies.

In this study, local factors like quality of the denture and flabby ridge were most often related to severe RRR in the maxilla than in the mandible. Most important is that about forty per cent of subjects had worn RPDs before becoming totally edentulous, and this seem to contribute to the alveolar resorption in both jaws. In the mandible, severe RRR was more specifically related to the number of CDs worn and systemic factors.

Nearly all of the subjects, 96% of CD wearers and 98% of RPD wearers, reported that they clean their dentures at least once every day. The most popular cleaning method was brushing. Three quarters of all subjects brushed their dentures by rinsing in water. They were performing the daily denture cleaning routines conscientiously, but obviously using ineffective methods. In spite of poor denture hygiene, no statistically significant difference in prevalence of mucosal lesions was found between those subjects who cleaned their dentures once a day or not at all, and those who cleaned the dentures twice a day or more frequently. Negative correlation was found between oral mucosal lesions and the daily soft tissue brushing.

In two fifths of the whole study group at least one oral mucosal lesion was detected. These lesions were most common among the edentulous CD-wearers: half of the edentulous subjects and one third of partly dentate partial denture wearers had oral mucosal changes. The total number of lesions per person correlated positively with the total number of subject's daily drugs. The prevalence of lesions not related to the use of dentures was rather low, less than 10%. The denture related oral mucosal changes were very common, inflammatory lesion under upper denture was the most frequent finding and it was recorded in 25% of the CD-wearers.

After the 5-year follow-up time, 46% of the basic Oral-HAS group participated in the re-examination. Forty per cent of them were edentulous. With the exception of one subject having only upper CD, all other edentulous subjects had a full set of CDs. Five persons in this group were "new edentulous" CD users. Sixty per cent of the follow-up group was partly dentate, having one or more natural teeth retaining. From 1990 to 1996, half of the subjects with prosthesis had lost one or more natural teeth, the mean number of remaining teeth was nine. Loss of natural teeth was related to wearing removable dentures and male gender at baseline. Prosthetic rehabilitation had changed during the 5-year follow-up in 44% of the participants. The elderly with removable dentures had also a higher salivary microorganism count and root caries incidence than those with natural dentition.

This study clearly showed that the objective and subjective treatment needs do not always meet in the elderly. Thus, adjustment of the existing dentures would often be enough to satisfy the patient, and be a better treatment option than replacing the old ones. Also the numerous missing teeth in the anterior arch indicate, that although the subjective needs for prosthetic treatment seemed to be relatively minor, a clear objective need for further prosthetic rehabilitation still existed.

The documented denture cleaning and wearing habits, as well as the prevalence of mucosal lesions support previously published studies. General mucosal lesions were found in 10% of the subjects. Denture related mucosal lesions were numerous, and found in some form in one quarter of the denture wearers.

The 5-year follow-up study revealed that minor changes in prosthetic rehabilitation, even among older population, are rather common. In these age groups the number of complete

denture wearers was high, but only few lost their last teeth in very old age. In most cases, these persons have already been borderline denture patients having only one or two natural teeth with poor prognosis. Considering the high number of oral microorganisms in persons with removable dentures and their association with loss of teeth, placement of removable prostheses should be carefully considered (V; Table 4). Shortened dental arch detained with fixed prostheses often guarantees sufficient chewing function and better oral health for the elderly.

Compared to earlier studies in Finland, this study showed a rather high average number of remaining teeth among the elderly in Helsinki. This does not exclude the fact that the number of missing teeth was also high, number of removable dentures high, and number of fixed prosthesis relatively low. The fact that only one participant had implant supported overdenture in the mandible is probably due to high costs involved in the implant treatments. The present study population was drawn from the public register already in 1989 and since then the situation has clearly changed in Finland.

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13. APPENDICES

Appendix 1

Questions concerning the state of present prosthetic rehabilitation, history of prosthetic rehabilitation, oral hygiene habits and subjective opinion about natural teeth and prosthesis.

I -How important do you consider retaining your own natural teeth?
(1) very important; (2) quite important; (3) not important.
II -Are you satisfied with your teeth?
(1) very satisfied; (2) satisfied; (3) not satisfied.
III -If you are satisfied, what do you think is the reason for the good condition of your teeth?
(1) you have always brushed your teeth well; (2) you have not eaten sweets very often; (3) you have visited your dentist frequently; (4) other reasons.
IV -If you are not satisfied, what do you think is the main reason for this discontent?
(1) appearance of the teeth; (2) inability to chew properly; (3) decayed teeth; (4) frequent toothache; (5) gingival bleeding; (6) removable dentures; (7) crowns and bridges; (8) bad taste in the mouth; (9) something else.
V -How would you consider your ability to chew?
(1) good; (2) satisfactory; (3) poor.
VI -What kind of prosthesis do you have in your upper jaw?
VII -What kind of prosthesis do you have in your lower jaw?
VIII -When did you get your first complete dentures?
(1) 0-10 years ago; (2) 11-20 years ago; (3) 21-30 years ago; (4) 31-40 years ago; (5) over 40 years ago.
IX -What was the reason for getting the first complete dentures?
(1) own teeth were lost because of decay; (2) own teeth loosened by themselves; (3) own teeth were removed because of their poor appearance; (4) own teeth were lost due to an accident.
X -How long have you worn the latest complete dentures (denture in both jaws)?
(1) 0-1 yr; (2) 2-5 yrs; (3) 6-10 yrs; (4) 11-20 yrs; (5) 21-30 yrs; (6) 30 years or more; (7) I do not remember.
XI -How would you consider your complete dentures (denture in both jaws)?
(1) good; (2) satisfactory; (3) poor.
XII -If you have missing teeth, which of them you would like to have replaced?

Appendix 2

Questions related to wearing complete dentures and denture hygiene habits.
I -How many times did you clean your denture(s) yesterday?
(1) not at all; (2) once; (3) twice; (4) more than twice
II -Do you clean the soft tissues covered by the denture?
(1) yes; (2) no
III- If yes, how did you do it?
(1) by rinsing; (2) by brushing; (3) by rinsing and brushing
IV –How often do you use denture fixative?
(1) daily; (2) occasionally; (3) never
V -If yes, what kind of fixative do you prefer?
(1) powder; (2) gel; (3) liquid

14. ORIGINAL PUBLICATIONS